in order to get the actual frequency. This can be done by the formula:

$$N_p = N_s\,[1 + .0018\,(t_p - t_s)\,].$$

To sum up, it has been shown: (1) that the frequency of a whistle or variator varies appreciably with temperature; (2) that temperature must be taken into account in calibrating one of these instruments; (3) that calibrations at different settings must be reduced to a standard temperature to be comparable; (4) that in calibrating by comparison with another wind instrument the temperature at which the comparison was made need not be considered, since both instruments vary to the same amount with temperature; but that the results of such a comparison are valid only for the temperature for which the standard was calibrated, unless a correction be made; and (5) that in calibrating by Kundt's method the temperature at which the determination is made is likewise of no account, the results being valid for the temperature for which the velocity of sound is taken in computing the frequency. Moreover, (6) formulae have been given for performing the various corrections.

XXV. Visual Quality as a Determinant of Clearness

By J. S. Smith

Are there certain color-qualities which make a special appeal to attention? If, for example, red and yellow were to appear simultaneously in the visual field, should we tend definitely to regard the one and to disregard the other; or, in general, is there any visual quality to which we are predisposed to attend? Gale[1] found that black on a white, and green on a black background are most effective for men, while for women red is the attracting color irrespective of background. But Gale apparently made no attempt to control the time of exposure, or to avoid successive contrast, adaptation, and the space-error. Furthermore, he employed only artificial illumination, and he failed to take introspections. It seemed advisable, therefore, to repeat the experiment.

Method and Apparatus.—We employed the method of paired comparisons. The stimuli were six colors of the Milton Bradley Spectral Scales: red (R), orange (O), yellow (Y), green (G), blue (B), violet (V), together with black (Bk) and white (W). These we mounted in one-inch squares, half an inch apart, on both black and white cards, five by eight inches; the black square was mounted on white, and the white square on black. The stimuli were presented in the Whipple tachistoscope, with an exposure of 160 sigma, in both daylight and artificial light, with dark adaptation. Care was taken that no color should appear in consecutive exposures. Since every color was presented with every other color on each background, there were 21 pairs of stimuli in each set. The cards were also shown inverted, to avoid any space error; so that for each illumination there were 42 observations with each background. Finally, every

[1] H. Gale, *Psychological Studies*, 1900, 55 ff.

series was shown three times over to every observer under all four conditions; that is, every observer made in all 504 judgments.

The observers, Mr. L. G. Meads (*M*), graduate student in psychology, Dr. W. S. Foster (*F*), instructor in psychology, and Miss M. F. Sturges (*S*), student in psychology, were instructed to report which of the colors shown was the more clear; if both were equally clear, they were to report 'equal.' After every series the observer was asked to report his experience in making the judgment of clearness.

Results.—Since every color was shown with every other color thirty-six times on each background and in each illumination, the frequency with which any one color may be judged as more clear varies between thirty-six and zero. The following table shows the frequencies of judgment and the rank-order of judgments, with both backgrounds and both illuminations, for each one of the three observers:

TABLE 1.

	Frequencies							Rank Order						
				Black background (daylight)										
	R	O	Y	G	B	V	W	1	2	3	4	5	6	7
F	0	25.5	28.5	20	8	10	34	W	Y	O	G	V	B	R
M	0	24	30	19	12	6	35	W	Y	O	G	B	V	R
S	0	33	28	21	13	6	25	O	Y	W	G	B	V	R
				White background (daylight)										
	R	O	Y	G	B	V	Bk	1	2	3	4	5	6	7
F	15.5	23	6	29.5	25	14	13	G	B	O	R	V	Bk	W
M	29	20	0	8.5	23	11.5	34	Bk	R	B	O	V	G	Y
S	9	36	11	27	26	13	4	O	G	B	V	Y	R	Bk
				Black background (artificial light)										
	R	O	Y	G	V	B	W	1	2	3	4	5	6	7
F	19.5	31	24.5	14	7	5	25	O	W	Y	R	G	B	V
M	14	28.5	25	17	0	6	35.5	W	O	Y	G	R	V	B
S	26	35	24	13.5	8.5	4	15	O	R	Y	W	G	B	V
				White background (artificial light)										
	R	O	Y	G	B	V	Bk	1	2	3	4	5	6	7
F	27.5	15.5	0	17	24.5	13	28.5	Bk	R	B	G	O	V	Y
M	32	18	0	15	18	14	29	R	Bk	B	O	G	V	Y
S	36	25	0	15	23	9	18	R	O	B	Bk	G	V	Y

The following excerpts from the introspective reports afford some indication not only of the nature of the experience but also of the criteria of judgment.

F. "When the exposure comes, one of three things happens: (1) I may really see only one color. This is particularly so where Y and O appear with a color considerably darker (on a white background); the latter is then seen first. (2) I may see both colors simultaneously, and clearness is equal. (3) I may see both colors simultaneously and one is clearer than the other. This is the most common occurrence." (Black background.) "Almost without exception the brighter color has been the clearer." "It seems to be the more intense color that is more clear, *i. e.,* the color which is brighter and more saturated. In general the colors are absolutely more clear." "I think that color on black would be more clear than color on white." "In general the more clear color is also the more distinct color." (White background.) "I have a general impression that attention goes to the more saturated colors and to the darker colors and, judging mostly from black and red, that saturation has greater compelling power than darkness."

M. (Black background.) "I seem to take the brighter color,—the one which was glary. I noticed no tendency to choose any particular color. I thought of a spot just behind the fixation point on the screen, and then I named the color which seemed to force itself upon me, the one which furnished the greater tendency to turn to, to attend to."

S. (Black background.) "Tendency for the light colors to be more clear; O looked shiny and was clearer than R. I remember that on the white background R was clearer." (White background.) "When there was light and dark color, the dark usually stood out; Y never got my attention (with artificial light), V only when darker than the other color. When R appeared with other colors it was seen at once and the others not noticed (the same thing was true when Bk and B appeared with light colors); R and O both seemed persistent, stood out immediately."

Discussion of the results.—The first impression made by the objective results is the large degree of individual difference. Two things are, however, obvious. (1) There was no predisposition for any one hue, which was common to all three observers. (2) The fact that observer *S* judged O as the more clear 129 times out of a possible 144 indicates an individual predisposition for that hue. Since no special predispositions can be clearly made out for the other two observers, and since the experiments with different backgrounds (all other conditions remaining the same) yield divergent results, there must be some factor, other than hue, which conditioned clearness. This conclusion is borne out by the introspective reports; the observers themselves believed that their attention was determined by lighter colors on dark backgrounds, and by darker colors on white backgrounds, and also by differences in chroma. We must therefore inquire as to the relative tint and chroma of the colors under the various conditions.

The arrangement of the stimuli in descending order of *tint* as measured by flicker photometry (the values in degrees of *black*) is as follows:

Daylight Y (22), O (190), G (193), V (282), B (292), R (314).
Artificial light: Y (21), O (114), G (234), V (288), R (301), B (317).
To determine the relative *chroma,* we asked a number of psychologically trained observers to arrange the stimuli in chromatic order

under all the four conditions. There was general agreement for the colors on white, but disagreement for the black background. In both cases the colors fall into certain groups within which discrimination is difficult. With the white background, the descending scale (with the grouping) is for daylight, B, GO, YRV; for artificial light, GO, RB, YV. With black backgrounds the diversity was such that we give the actual judgments (with grouping):

Obs.	Daylight	Obs.	Artificial light
W.	B, O–G–Y, R, V	*W.*	G–R–O, B–Y–V.
B.	B, O–R–G–Y, V	*R.*	G–O–R, Y–B–V.
F.	O–B, G–Y, R, V	*B.*	O–G–R, Y–B–V.
C.	O–Y–R–G–B, V		

The safest conclusion is that, on a black background in daylight, the colors are of the same order of chroma, V alone excepted; while in artificial light they fall into two groups, within each of which the chroma is of the same order. The chroma of B and R seems to be especially sensitive to the objective conditions; while O and G maintain a high and V a low position under all four conditions. A similar result is found with regard to tint; Y and V are of approximately the same tint under both illuminations; G and O, which are nearly equal in daylight, differ by 120° of black in artificial light. These facts account easily enough for a general shift of clearness under the various conditions; but they do not explain the individual differences of judgment in any single series. Since we had no further control of the variable factors, and since the number of judgments is too small to render the differences upon which the rank-orders are based positively significant, our data are inadequate to a quantitative treatment. We can offer only a qualitative and tentative explanation.

We suppose that our observers were differently disposed toward the different factors, and that the dispositions were variously actualized by the objective conditions. For example, *in the experiments in daylight and with a black background, we find a general agreement among observers;* the rank-orders are the same for *F* and *M,* except for a one-place transposition of colors nearly equal in tint; while observer *S* differs from *M* only in the exchange of positions of O and W. Apart from these transpositions, *the reports of all observers reproduce the descending scale of tint.* We have seen that, under the conditions of the series, the colors (V excepted) are of the same order of chroma. The objective conditions would therefore favor predispositions for hue and for light-contrast, and would inhibit a predisposition for chroma. The predilection of *S* for O appears; otherwise, contrast-effect seems to be the sole condition of attention for all three observers. *On the white background, however, chroma apparently becomes more effective;* and there seems to be no reason why, with any given pair of colors, either hue, tint or chroma (or a combination of them) should not be determining, according to the predisposition of the observer at the moment. If this be true, we might expect disagreement among observers under the conditions of our own experiment.

Summary.—(1) We have found no predisposition for any one hue, common to all observers; we find evidence, however, of a predisposition for a certain range of hues in the case of one observer.

(2) The problem is not so simple as Gale thought it to be. Aside from hue, tint or chroma, or both, may also be effective to determine attention; and the importance of the variable factors depends partly upon objective conditions, and partly upon the predisposition of the observer. The judgments are not difficult; and now that we have some idea of the factors involved, a repetition of the experiment with stricter control of stimuli should yield a satisfactory answer to our general question.

XXVI. A Preliminary Study of Vowel Qualities

By J. D. Modell and G. J. Rich

The experiments reported in this paper were undertaken as a test of Köhler's earlier work with only approximately pure tones. Köhler employed tuning forks as stimuli; and his observers reported that the series of tones ranging from 163 to 4,000 v. d. gave a series of vowel qualities which could be arranged like those of color. Just as in the case of color there is a series of qualities from red through several nuances of orange to yellow, and from yellow a second series to green, and so on, so there runs a series in the phenomenal tone-system from *u* (moon) through *u-o, o-u* to *o,* and from *o* through *o-a, a-o* to *a* (father), and so on through *e* (prey) to *i* (machine).[1] In later experiments, in which he used Stern variators with interference apparatus, Kohler determined more accurately the pitch of the pure vowels; added those of *s, f,* and *ch* to the upper, and of *m* to the lower region of the scale; and concluded that the pure vowels fall regularly in octaves.[2] Since, however, we wished to know whether observers untrained in continental vowels would give the same judgments, and since Köhler himself holds that vowel qualities are to be found in all relatively simple tones, we have restricted our investigation to the preliminary aspects of the problem.

Apparatus.—We used as stimuli four Stern variators which gave a total range of 100-1200 v. d., a piston-whistle of 1072-3400 v. d., and an Edelmann-Galton whistle from 3560 to 5770 v. d. The variators were tuned by beats with König forks, and the two whistles by the Kundt dust-method. In our first experiments the whistles were blown by pressure on a rubber bulb; but since the pressure could not be rigorously controlled, we later actuated all instruments by air from a tank-gasometer. Weights were added, to give sufficient pressure for the high variator and the whistles. A record was kept of the amount of pressure both at the tank and at the mouth of the instrument, since it was found necessary to adjust the amount of pressure for the particular instrument if we were to obtain the best quality of tone. The pressure varied from 1.8cm. of water for the 300-600 variator to 14.0cm. for the Galton and 15.0cm. for the piston-whistle. All instruments were so connected with the tank that they could be instantly actuated at full pressure. There were two sources of error in the apparatus; a constant error of not more than 1%

[1] W. Köhler, Akustische Untersuchungen, II, *Zeit. f. Psych.,* lviii, 1911, 59 ff.

[2] See also *Zeit. f. Psych.,* lxiv, 1913, 92 ff.